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Indian Standard

SPECIFICATION FOR VARNISH BONDED GLASS-FIBRE COVERED COPPER CONDUCTORS

PART I ROUND WIRES

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Indian Standard
SPECIFICATION FOR VARNISH BONDED GLASS-FIBRE COVERED COPPER CONDUCTORS
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Indian Standard
SPECIFICATION FOR VARNISH BONDED GLASS-FIBRE COVERED COPPER CONDUCTORS
PART I ROUND WIRES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 6 July 1968, after the draft finalized by the Winding Wires Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 Varnish bonded glass-fibre covered conductors could be used for various applications, depending on the type of varnish used as bonding material. The complete conductor would be classified depending on the varnish, for thermal stability in service as detailed in IS : 1271-1958*.

0.3 It is necessary that the impregnating varnish should be compatible with the bonding material. In the absence of a functional test to evaluate the compatibility, the question of compatibility must be kept in mind by the user. However a test to evaluate the compatibility is under consideration.

0.4 In formulating this standard, assistance has been derived from B.S. 1933 : Part 1 : 1953 Varnished bonded glass-covered copper conductors : Part 1 Round wire issued by the British Standards Institution.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960†. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers the requirements and methods of test for single and double glass-fibre covered copper conductors of sizes from 0·250 mm to 4·000 mm, the glass-fibre being bonded with suitable highly polymerized thermosetting varnish of temperature index at least 130°C

NOTE — The individual temperature ratings for the different type of varnishes may be agreed upon between the manufacturer and the user.

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*Classification of insulating materials for electrical machinery and apparatus in relation to their thermal stability in service. (Since revised).

†Rules for rounding off numerical values (*revised*).

1.1.1 Stranded conductors, covered conductors containing a layer of material other than bonded glass, and glass braided coverings are not included in this standard.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Wire — Varnish bonded glass-fibre covered solid conductor of circular section within the specified range of diameters.

2.2 Tolerance — The permissible deviation of an actual magnitude from that prescribed.

2.3 Increase in Diameter — The difference between the diameter over the complete glass-fibre covering and the diameter of the conductor.

2.4 Temperature Index — The temperature in degrees Celcius corresponding to an extrapolated life of 20 000 h on an Arrhenius plot.

3. CONDUCTOR

3.1 Material — The material shall consist of high conductivity annealed round copper conductor having the following properties.

3.1.1 *Physical Constants for Annealed Copper* — The constants given in **3.1.1.1** to **3.1.1.4** are based on standards fixed by the International Electrotechnical Commission.

3.1.1.1 *Coefficient of linear expansion* — The coefficient of linear expansion of annealed copper over a temperature range of 0° to 150°C has been taken as 0·000 017 per degree Celsius.

3.1.1.2 *Density* — The density of annealed copper at a temperature of 20°C shall be taken as 8·89 g/cm^3.

3.1.1.3 *Resistance* — The resistance at 20°C of a conductor of annealed copper of one metre in length and of a uniform cross-sectional area of one square millimetre shall be taken as 0·017 241 ohm.

3.1.1.4 *'Constant mass' temperature coefficient at* 20°C — At a temperature of 20°C, the 'constant mass' temperature coefficient of resistance of annealed copper measured between two potential points rigidly fixed to the conductor, the metal being allowed to expand freely, shall be taken as 0·003 93 per degree Celsius or 0·003 93 = 1/254·45 per degree Celsius.

3.2 Diameter

3.2.1 The diameters and tolerances on diameters of conductors shall be as given in Table 1.

3.2.2 *Measurement of Diameter* — The diameter shall be measured by the method given in Appendix A. The average diameter when measured by this method shall be within the tolerance limits given in Table 1.

TABLE 1 DIAMETERS AND RESISTANCES OF VARNISH BONDED GLASS-FIBRE COVERED CONDUCTORS

(*Clauses* 3.2.1, 3.2.2, 3.3.1, 3.3.2 *and* 4.2)

NOMINAL CONDUCTOR DIAMETER	TOLERANCE ± *t*	SINGLE COVERING		DOUBLE COVERING		RESISTANCE IN OHMS PER METRE AT 20°C		
		Overall Diameter *Max*	Increase in Diameter *Min*	Overall Diameter *Max*	Increase in Diameter *Min*	Nominal	*Max*	*Min*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
mm	mm	mm	mm	mm	mm			
0·250	0·004	0·380	0·075	0·456	0·150	0·351 2	0·365 9	0·337 4
0·280	0·004	0·410	0·075	0·486	0·150	0·280 0	0·290 7	0·269 8
0·315	0·004	0·445	0·075	0·521	0·150	0·221 2	0·228 9	0·213 9
0·355	0·004	0·486	0·075	0·562	0·150	0·174 2	0·179 7	0·168 9
0·400	0·005	0·531	0·075	0·607	0·150	0·137 2	0·141 9	0·132 7
0·450	0·005	0·582	0·075	0·658	0·150	0·108 4	0·111 8	0·105 1
0·500	0·005	0·632	0·075	0·708	0·150	0·087 81	0·090 37	0·085 34
0·560	0·006	0·693	0·075	0·769	0·150	0·070 00	0·072 15	0·067 94
0·630	0·006	0·763	0·075	0·839	0·150	0·055 31	0·056 87	0·053 81
0·710	0·007	0·844	0·075	0·920	0·150	0·043 55	0·044 81	0·042 34
0·750	0·008	0·885	0·075	0·961	0·150	0·039 03	0·040 22	0·037 88
0·800	0·008	0·935	0·075	1·011	0·150	0·034 30	0·035 30	0·033 34
0·850	0·009	0·986	0·075	1·062	0·150	0·030 38	0·031 31	0·029 50
0·900	0·009	1·036	0·075	1·112	0·150	0·027 10	0·027 89	0·026 34
0·950	0·010	1·087	0·075	1·163	0·150	0·024 32	0·025 06	0·023 62
1·000	0·010	1·135	0·075	1·215	0·150	0·021 95	0·022 59	0·021 34
1·060	0·011	1·200	0·075	1·275	0·150	0·019 54	—	—
1·120	0·011	1·260	0·075	1·335	0·150	0·017 50	—	—
1·180	0·012	1·320	0·075	1·395	0·150	0·015 77	—	—
1·250	0·013	1·390	0·075	1·465	0·150	0·014 05	—	—
1·320	0·013	1·460	0·075	1·535	0·150	0·012 60	—	—
1·400	0·014	1·540	0·075	1·615	0·150	0·011 20	—	—
1·500	0·015	1·640	0·075	1·720	0·150	0·009 757	—	—
1·600	0·016	1·745	0·075	1·820	0·150	0·008 575	—	—
1·700	0·017	1·845	0·075	1·920	0·150	0·007 596	—	—
1·800	0·018	1·945	0·075	2·020	0·150	0·006 775	—	—
1·900	0·019	2·045	0·075	2·120	0·150	0·006 081	—	—
2·000	0·020	2·145	0·075	2·225	0·150	0·005 488	—	—
2·120	0·021	—	—	2·395	0·200	0·004 884	—	—
2·240	0·022	—	—	2·515	0.200	0·004 375	—	—
2·360	0·024	—	—	2·640	0·200	0·003 941	—	—
2·500	0·025	—	—	2·780	0·200	0·003 512	—	—
2·650	0·027	—	—	2·930	0·200	0·003 126	—	—
2·800	0·028	—	—	3·080	0·200	0·002 800	—	—
3·000	0·030	—	—	3·285	0·200	0·002 439	—	—
3·150	0·032	—	—	3·435	0·200	0·002 212	—	—
3·350	0·034	—	—	3·690	0·200	0·001 956	—	—
3·550	0·036	—	—	3·890	0·250	0·001 742	—	—
3·750	0·038	—	—	4·095	0·250	0·001 561	—	—
4·000	0·040	—	—	4·345	0·250	0·001 372	—	—

3.3 Resistance

3.3.1 The resistance of conductors at 20°C shall be in accordance with appropriate values in col 7 to 9 of Table 1.

NOTE — The conductors shall be checked for diameter and/or resistance in the following manner:

Diameter mm		*Measurement*
Over	Up to and Including	
—	1·000	By resistance and diameter
1·000	—	Only by diameter

3.3.2 *Tolerance on Resistance* — The resistance values in col 8 and 9 of Table 1 are respectively the maximum and minimum permissible values and shall be calculated by the method described in Appendix B.

3.3.3 The resistance of the conductor shall be measured as direct current resistance at 20°C with a method providing an accuracy of 0·5 percent. If the resistance is measured at a deviating temperature, the resistance at 20°C is calculated by multiplying the result obtained by the correction factor K calculated from

$$K = \frac{1}{1 + 0{\cdot}003\,93\,(t - 20)}$$

where t = actual temperature in °C during measurement.

3.4 Freedom from Defects — The conductor shall be finished clean and smooth and shall substantially be free from slivers, spills, cracks and other defects.

4. INSULATION

4.1 General — The conductor shall be covered with one or two layers of glass-fibre, lapped firmly, evenly, closely and continuously around the conductor. The glass-fibre shall be of a quality suitable for electrical uses and should employ 'E' glass (having alkali content less than 1 percent). The glass-fibre covering shall, in all cases, be firmly bonded with a suitable highly polymerized varnish and it is desirable that the varnish is applied after each layer of insulation.

4.2 Overall Diameter and Increase in Diameter — The overall diameter when determined as described in Appendix A, shall not exceed the appropriate values in col 3 and 5 of Table 1. The increase in diameter shall be not less than the appropriate values in col 4 and 6 of Table 1.

5. TESTS

5.0 Atmospheric Conditions for the Tests — The electrical and mechanical tests shall be made at a temperature between 10° and 40°C at a relative humidity not exceeding 85 percent unless otherwise specified in the following clauses.

5.1 Bending Test

5.1.1 *Test at Ambient Temperature* — A sample of the glass-fibre covered wire shall be wound around a polished metal mandrel, having a diameter equal to eight times the nominal conductor diameter for wire of 1·000 mm diameter (bare) and finer and ten times the nominal conductor diameter for wire of diameter larger than 1·000 mm (bare). Sufficient tension shall be used to give an even and compact layer. The covering shall not open sufficiently to expose the bare copper to view when examined by normal eye sight under diffused light.

5.1.2 *Test at Elevated Temperature* — Samples which have been subjected to heat treatment as described in Appendix C shall be capable of passing the bending test specified in 5.1.1.

5.2 Breakdown Voltage Test — The wire shall meet the requirements of 5.2.1 and 5.2.2 when tested at room temperature and at rated temperature, respectively.

5.2.1 *Test at Room Temperature* — Samples shall be subjected to a breakdown voltage by the method described in Appendix D. At least four of the five samples shall not breakdown at voltages less than those given in Table 3. Fifth sample shall not breakdown at a voltage less than 50 percent of the required value.

5.2.2 *Test at Rated Temperature* — When tested by the method described in Appendix D, at the rated temperature, at least four of the five samples tested shall not breakdown at voltages less than those given in Table 2. Fifth sample shall not breakdown at a voltage less than 50 percent of the required value.

TABLE 2 BREAKDOWN VOLTAGE

Nominal Conductor Diameter		Minimum Breakdown Voltages (rms)			
Over	Up to and Including	At Room Temperature		At Rated Temperature	
		Single covering	Double covering	Single covering	Double covering
(1)	(2)	(3)	(4)	(5)	(6)
mm	mm	V	V	V	V
	2·00	270	540	200	405
2·00	2·50	—	720	—	540
2·50	3·30	—	360	—	270
3·30	4·00	—	450	—	340

5.3 Test for Tackiness — A sample of the covered wire shall be heated and maintained at a temperature of 65°C for five minutes. The covering shall not become tacky to the touch.

5.4 Elongation of the Finished Conductor — A sample of finished conductor 250 mm long shall be steadily elongated at a rate of approximately 300 mm per minute until the wire fractures. The elongation at fracture shall not be less than the appropriate value given in Table 3.

TABLE 3 MINIMUM ELONGATION OF COVERED WIRE

NOMINAL DIAMETER OF BARE WIRE mm	MINIMUM ELONGATION, PERCENT
0·250 to 0·750	20
0·800 to 1·600	25
over 1·600	30

6. PACKING, WRAPPING AND LABELLING

6.1 The wire shall be wound on reels, packed, wrapped and labelled in accordance with IS : 482-1962*.

6.1.1 The label which is to be securely attached to reel shall have the following information:

a) Manufacturer's name and trade-mark,
b) Type of covering,
c) Diameter of wire, and
d) Weight of wire.

6.2 The wire may also be marked with the ISI Certification Mark.

NOTE — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act and the Rules and Regulations made thereunder. The ISI Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by ISI and operated by the producer. ISI marked products are also continuously checked by ISI for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the ISI Certification Mark may be granted to manufacturers or processors, may be obtained from the Indian Standards Institution.

APPENDIX A

(*Clauses* 3.2.2 *and* 4.2)

MEASUREMENT OF CONDUCTOR DIAMETER AND OVERALL DIAMETER

A-0. The measurement of the diameter of the conductor and the overall diameter of the covered wire shall be determined as follows.

A-1. Discard approximately 1·5 metres from the reel and measure the diameter over the glass-fibre covering. Remove the insulation at this point by heating the piece of wire and dipping it in methylated spirit. Wipe it and then measure the diameter of the conductor. Repeat these measurements twice at 300 mm intervals at approximately 120 deg angular displacement.

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*Specification for reels for covered, solid, round electrical winding wire (*revised*). (Since revised).

A-2. The average values of the three results of each series of measurements shall be taken as the overall diameter of the covered wire and the diameter of the conductor respectively.

A-3. The difference between these averages is the increase in diameter due to the glass-fibre covering.

A-4. The measurement shall be made with an accuracy better than 0·002 mm. If a micrometer is used it shall be fitted with a pressure indicator. The spindle and the anvil of the micrometer shall have a diameter of 5 to 8 mm. The measurement shall be made with a pressure of 0·75 to 1·25 N. Alternatively for wires less than 0·5 mm a pressure of 1 to 3 N may be used.

APPENDIX B

(*Clause* 3.3.2)

METHOD OF CALCULATION OF LINEAR RESISTANCE

B-1. LIMITS OF ELECTRICAL RESISTANCE

B-1.1 The limits of electrical resistance are calculated on the following basis.

B-1.1.1 *Conductors of Diameter Up to and Including* 1·000 *mm* — The maximum and minimum values of resistance are calculated from the maximum and minimum values of resistivity by taking into account for each diameter the relevant dimensional tolerance.

The linear resistance is calculated from:

$$R_{Max} = \rho_{Max} \cdot q^{-1}_{Min} \text{ (ohm/m)}$$

$$R_{Min} = \rho_{Min} \cdot q^{-1}_{Max} \text{ (ohm/m)}$$

Where q_{Max} and q_{Min} are respectively the maximum and minimum conductor cross-section in mm^2, taking into account for each diameter the relevant dimensional tolerance.

B-1.1.1.1 The maximum and minimum values of resistivity of copper are given below:

$$\rho_{Max} = 1/57{\cdot}5 \text{ (ohm}\cdot\text{mm}^2\text{/m)}$$

$$\rho_{Min} = 1/58{\cdot}5 \text{ (ohm}\cdot\text{mm}^2\text{/m)}$$

APPENDIX C

(*Clause* 5.1.2)

HEAT TREATMENT FOR BENDING TEST AT ELEVATED TEMPERATURE

C-1. Samples of wire, unstretched and unbent shall be heated for 48 hours in an oven at a temperature of 20°C higher than the temperature of the class of insulation for which the wire is intended, in free air. The samples shall be then allowed to cool to room temperature.

APPENDIX D

(*Clauses* 5.2.1 *and* 5.2.2)

BREAKDOWN VOLTAGE TEST

D-1. TEST FOR CONDUCTOR SIZES UP TO AND INCLUDING 2·500 mm DIAMETER

D-1.1 Two separate layers of the glass-fibre wire are wound, one on top of the other in opposite direction, for a length of approximately 25 mm on a smooth mandrel of insulating material, the diameter of the mandrel being as specified for the bending test in **5.1.1.**

D-1.2 The ends are held firmly while the layers are being wound, only sufficient tension being applied to give even and compact layers and to ensure close contact between them without stretching the wire.

D-1.3 The glass covering is removed from one end of each layer, and a test voltage is applied in accordance with **D-3.**

D-2. TEST FOR CONDUCTOR SIZES OVER 2·500 mm DIAMETER

D-2.1 Five electrodes are prepared by applying a strip of thin metal foil having a width of 6·0 mm to the centre of a pressure sensitive tape 12·0 mm wide. The pressure sensitive tape should not extend beyond the ends of the metal foil.

D-2.2 A sample of wire of such length is used that the five electrodes can be applied at intervals of approximately 50 mm. The electrodes are applied to the wire with the tape at right angle to the wire and the foil in contact with the wire. The tape is wrapped smoothly and firmly around the wire.

D-2.3 The glass covering is removed from one end of the sample and a voltage is applied between the conductor and each electrode in turn, thus giving five tests on the sample of wire.

D-3. TEST VOLTAGE

D-3.1 The test voltage is alternating and of a nominal frequency of 50 Hz and approximately sinu-soidal, the peak factor being within the limits of $\sqrt{2} \pm 5$ percent (1·34 to 1·48). The test transformer should have a rating of at least 500 VA and should provide a current of essentially undistorted wave from under test condition.

D-3.2 The voltage is applied at zero and increased at a uniform rate of approximately 100 V per second until breakdown occurs. In the event of breakdown occurring in less than 5 seconds, the rate of increase is reduced. Where the breakdown voltage is equal to or greater than 2 500 V the rate of rise should be 500 V per second.

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